(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 181 506
A2

# (12) EUROPEAN PATENT APPLICATION

(21) Application number: 85112914.8

(22) Date of filing: 11.10.85

(51) Int. Cl.⁴: H 01 L 41/08
G 01 S 7/52

(30) Priority: 15.10.84 US 661082

(43) Date of publication of application:
21.05.86 Bulletin 86/21

(84) Designated Contracting States:
AT BE CH DE FR GB IT LI NL SE

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## (54) Flexible piezoelectric transducer assembly.

(57) A flexible piezoelectric transducer assembly for producing sonar signals for transmission underwater and for detecting reflected sonar signals. The assembly includes a generally flat, flexible casing formed with a plurality of compartments, each of which is for receiving a piezoelectric element. A plurality of piezoelectric elements are disposed in each of the compartments and are coupled by way of conductors to electronic circuitry which produces electrical signals for stressing the piezoelectric elements and which processes electrical signals produced by the piezoelectric element in response to reflected sonar signals. The piezoelectric elements are spaced apart in the casing to allow flexing and bending, while also maintaining high packing density. The piezoelectric elements are also selected to have low cross-coupling characteristics.

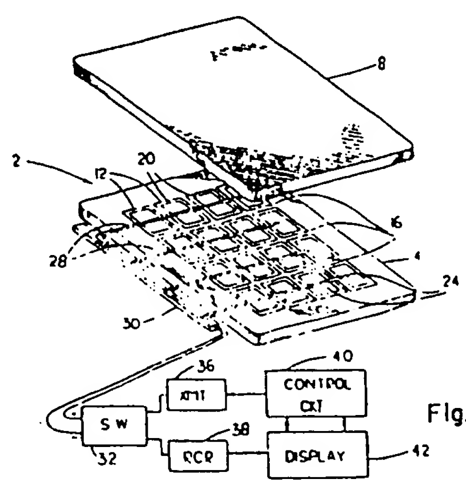


Fig. 1

Transducers typically used in underwater sonar equipment consist of either a single crystal or ceramic element or a rigid array of elements. It has been recognized that it would be desirable to have a flexible, conformable transducer which could be placed on various shaped surfaces for use. If a rigid transducer were applied to such surfaces and the surfaces were flexed or bent to any extent, the transducer could be damaged. A flexible, conformable transducer, however, would not only allow for ease of attachment to different shaped surfaces, but would also accommodate flexing and bending of the surface on which the transducer was placed.

There have been a number of proposals for providing flexible transducers including grinding up of piezoelectric material, embedding the material in an elastic material, and then attempting to polarize the entire unit so that it will function as a piezoelectric device. This type of unit, however, is typically very difficult to manufacture, sensitive to hydrostatic pressure changes and lacking in uniformity. Also, it is difficult to achieve consistency of characteristics from one unit to the next.

elements, each disposed in a different compartment of the encasement, and flexible conductors or conductive coatings which are arranged to extend through the encasement into contact with the elements for carrying externally generated electrical signals to the elements to stress the elements, and for carrying to a signal processor or other utilization device electrical signals produced by the piezoelectric elements when the elements are stressed.

With the above construction, the encasement holding the piezoelectric elements may be flexed or bent to conform to different mounting surface shapes. Advantageously, each piezoelectric element is polarized prior to installation in the encasement and so manufacture of the transducer assembly is simplified. A variety of materials might be used for the encasement including polyurethane, polyethelene, neoprene rubber, etc.

In the drawings:

The above and other objects, features and advantages of the invention will become apparent from a consideration of the following detailed description presented in connection with the accompanying drawings in which:

FIG. 7 is a perspective view of still another embodiment of a piezoelectric element which could be used in the FIG. 5 assembly.

Referring now to the drawings:

Referring to FIG. 1, there is shown an illustrative embodiment of a flexible planar piezoelectric transducer assembly which includes a two-piece housing or casing 2 having a base section 4 and a cover section 8. Both sections are made of a flexible, resilient material such as polyurethane, polyethelene, neoprene rubber, etc. When the cover section 8 is placed over and secured to the base section 4, the casing will present a generally flat profile as best seen in FIG. 2. The cover section 8 may be secured to the base section 4 by a suitable bonding agent such as polyurethane. The casing is formed to be generally square, but could take other shapes such as rectangular, circular, triangular, etc.

Formed in the base section 4 of the casing are a plurality of generally rectangular compartments 12. These compartments are formed to be fairly closely packed and nested in the manner shown in FIG. 1 to provide precise spacing of piezoelectric

applying electrical signals to the elements. Such films could be any suitable conductive material such as silver, a silver alloy, etc.

The piezoelectric elements 20 are selected to possess low cross-coupling to thereby reduce response in unwanted modes of operation and enable use of the elements over a wide band of frequencies without significant sensitive degradation. Suitable piezoelectric material for achieving this characteristic include lead mataniobate and lead titanate, among others.

Conductive strips of material 28 are placed in contact with each of the conductive films 24 on the upper surfaces of the piezoelectric elements 20, with conductive strips 28 extending through the casing to a bus 30 which is coupled to a transmit/receive switch 32. Conductive strips of material 34 (see FIG. 2) are placed in contact with conductive films positioned on the bottom surfaces of each of the piezoelectric elements 20 to extend through the casing also to the bus 30. The conductive strips 28 and 34 could advantageously be strips of silver, copper, etc., held in contact with the conductive films by spot welding, soldering or conductive adhesive. Alternatively, the conductive

20 are thus caused to produce, for example, sonar signals for underwater transmission. Reflected sonar signals intercepted by the piezoelectric elements 20 stress the elements and cause them to produce electrical signals which are applied via the switch 32 to the receiver and signal processor 38. The receiver and signal processor 38 process these signals and then signals the display unit to display information representing the location and shape, for example, of underwater objects from which the sonar signals are reflected. The circuitry described is conventional, shown only for illustrative purposes, and does not form any part of the invention.

The overall size of the transducer assembly could be whatever is desired by the user, but would depend in part on the number of piezoelectric elements to be utilized. Advantageously, the piezoelectric elements 20 would have widths and lengths of between about 1/8 of an inch and several inches, and would have thicknesses of between about 1/100 of an inch and 1 inch. These dimensions facilitate ease of manufacture and piezoelectric poling. Of course, the smaller the piezoelectric element, the greater would be the flexibility and conformability of the transducer assembly. Employment

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could also be employed as earlier indicated. It is desirable, however, that the piezoelectric elements be closely packed and nested together and this is accommodated by either the rectangular or triangular shape.

FIG. 4 shows a side, fragmented cross-sectional view of a transducer assembly wherein sheets of conductive material 54 and 58 are respectively placed to contact all of the individual conductive films placed on the upper surfaces of the piezoelectric elements, and to contact all of the films or electrodes on the bottom surfaces of the elements. These conductive sheets would be provided for carrying externally produced signals simultaneously to all of the piezoelectric elements, and for carrying signals produced by all of the elements simultaneously to an external sink. This provision of conductive sheets of material is an alternative to the conductive strips 28 and 34 shown in FIG. 1. Advantageously, the conductive sheets would be made of a composition of conductive particles and an elastomer, to provide flexibility for bending, etc.

FIG. 5 shows a partially cutaway view of a line array of piezoelectric elements 60 placed in a

radially polarized hollow cylinders were used, the conductors would be coupled to the inside and outside surfaces of the cylinders as shown in FIG. 7.

It is to be understood that the above-described arrangements are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the spirit and scope of the present invention and the appended claims are intended to cover such modifications and arrangements.

2. A transducer assembly as in Claim 1 wherein said encasement is formed of a generally planar base section an upper side of which is formed with said compartments, and a top section for placement on the upper side of the base section to enclose the compartments.

3. A transducer assembly as in Claim 1 wherein said encasement is made of polyurethane.

4. A transducer assembly as in Claim 1 wherein said encasement is made of polyethelene.

5. A transducer assembly as in Claim 1 wherein said encasement is made of rubber.

6. A transducer assembly as in Claim 1 wherein the compartments of the encasement holding the piezoelectric elements are formed in a closely packed and nested arrangement in the encasement.

7. A transducer assembly as in Claim 6 wherein the compartments and piezoelectric elements are generally polygonal in shape and dimensioned so that the elements fit snugly in the compartments.

14. A transducer assembly as in Claim 1 wherein the piezoelectric elements are held in place in the compartments by an adhesive.

15. A transducer assembly as in Claim 1 wherein the conduction means comprises

conductive sheets disposed on opposing sides of piezoelectric elements, and

conductive strips of material placed in contact with the conductive sheets and extending through the encasement to carry electrical signals from an external source to the sheets, and from the sheets to external electronics.

16. A transducer assembly as in Claim 15 wherein said conductive strips are composed of a composition of conductive particles and elastomer.

17. A transducer assembly as in Claim 1 wherein the conduction means comprises

a first sheet of conductive material disposed in contact with one side of each of the piezoelectric elements,

a second sheet of conductive material disposed in contact with the other side of each of the elements, and

19. A flexible piezoelectric transducer assembly comprising

an array of spaced-apart piezoelectric elements arranged generally in a line and selected to have low cross-coupling characteristics,

conductor means coupled to the piezoelectric elements for carrying electrical signals thereto to stress the elements, and for carrying electrical signals produced by the elements when the elements are stressed,

means for supporting the piezoelectric elements in the array, and

means for preventing external access of fluid to the elements.

20. A transducer assembly as in Claim 19 wherein said supporting means comprises a sleeve means in which are disposed the piezoelectric elements.

21. A transducer assembly as in Claim 20 wherein the preventing means comprises a nonconductive encapsulant disposed about the piezoelectric elements to prevent access of fluid to the elements.

22. A transducer assembly as in Claim 19 wherein said piezoelectric elements comprise

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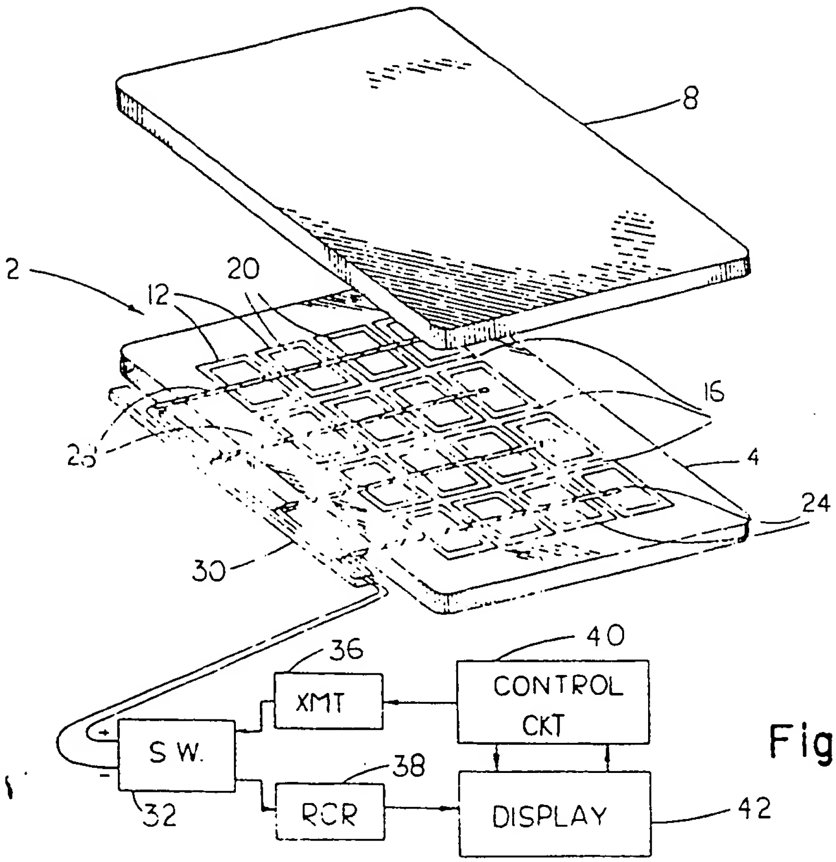


Fig. 1

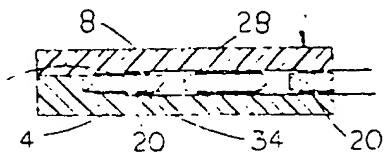


Fig. 2

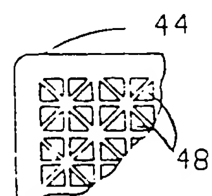


Fig. 3

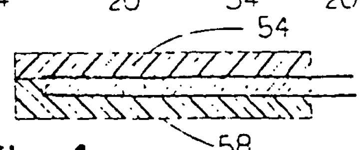


Fig. 4

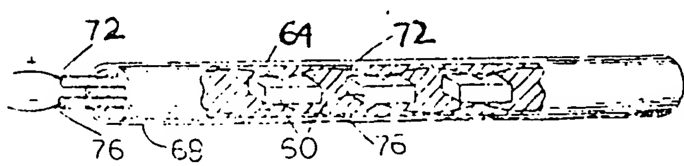


Fig. 5

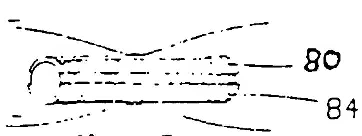


Fig. 6

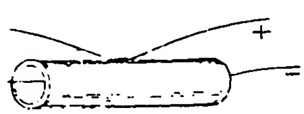

Fig. 7